[1.]A.M. RAJESH, [2.]Mohamed KALEEMULLA, [3.]Saleemsab DODDAMANI, [4.]K.N. BHARATH

DEVELOPMENT AND CHARACTERIZATION OF HYBRID ALUMINUM METAL MATRIX COMPOSITES

[1.]Department of Mechanical Engineering, SJM Institute of Technology, Chitradurga, Karnataka, INDIA
[2.]Department of Studies in Mechanical Engineering, U B.D.T. College of Engineering, Karnataka, INDIA
[3.]Department of Mechanical Engineering, Jain Polytechnic, Davangere, Karnataka, INDIA
[4.]Department of Mechanical Engineering, GM Institute of Technology, Davangere, Karnataka, INDIA

Abstract: In the present investigations, the hardness test is conducted on Vickers' hardness tester at room temperature for both the age hardening and without age hardening conditions. Al7075 has chosen as the matrix material. HMMCs are produced utilizing stir casting route for enhancing the hardness number. The reinforcement used is silicon carbide with 5%,10%, &15% weight percentage and $Al2O_3$ as the another reinforcement in 5%,10%, &15% weight percentage. In the aluminum matrix microstructural characterization reveal the homogeneous mixing of reinforcements. The density of composite is incremented with the increase in weight fraction. The result reveals that the addition of silicon carbide and alumina particles in aluminum matrix improves the mechanical properties.
Keywords: Composites, SiC, Alumina, compression, Hardness with and without heat treatment

INTRODUCTION

MMCs comprise of an alloy or a metal as the matrix and a reinforcement such as the particles, short fibre or whisker and/or long fibre. MMCs were a group of material with perspective for a broad collection of applications in structural management. Their properties such as light in weight, superior strength and resistance to wear are the requirement for the aviation and automobile industries.

Most commonly used matrixes are magnesium, copper, titanium, and zinc. The most commonly used reinforcements are silicon carbide, alumina, boron, graphite and fly ash. The applications of these composites are primarily in aviation, vehicle engineering, marine and turbine compressor engineering. MMCs are also used for light weight as well as for high temperature applications. Discontinuously or particle reinforced MMCs have turned out to be extremely mainstream since they are more affordable than long fiber fortified composite and it has generally isotropic properties contrasted with fibre reinforced composite [1].

Discontinuously reinforced MMCs are much less expensive to fabricate than continuously reinforced composites. Consequently, performance enhancement of the matrix comes at lower additional costs with discontinuous reinforcements compared with aligned reinforcements. Particulate reinforced MMCs are not expensive to manufacture than reinforced composites. Accordingly, performance improvement of the matrix comes at lesser expenses with particulate reinforcements compared with fiber aligned reinforcements. In addition, particulate reinforced composites exhibit the isotropic properties [2], whereas the properties of composites with fiber aligned reinforcements are highly anisotropic. Thus, in applications requiring isotropic properties, less expensive, particulate reinforced composites can do better than fiber reinforced composites. Typically, ceramics and graphitic materials are used as reinforcement phases in particulate reinforced MMCs. Some common reinforcements for aluminium matrices are SiC, Al_2O_3, B_4C, and graphite [3].

Singla et al [4] developed aluminium alloy/ SiCp composites of varying weight fractions of silicon carbide (5–30%) by stir casting techniques using a two step–mixing method. Results showed that impact strength and hardness increased with an increment in weight percentage of silicon carbide.

G. B. V Kumar et.al [5] evaluated tensile strength, hardness and wear resistance characteristics of Al7075–Al_2O_3 and A6061–SiCp composite. The liquid metallurgy method has been utilized to fabricate the composites. The addition of reinforcements i.e. SiC and Al_2O_3, shows the improved mechanical properties such as resistance to wear, hardness and strength of the respective composites.

Komai et al [6] conducted the experimentation to determine the mechanical properties of Al7075–SiC composite. From the result, it is observed that the better mechanical properties of A7075–SiC whiskers composite have been obtained. Rupa Dasgupta et al [7] conducted experimentation to find the wear behavior and hardness of the A7075–SiC composite. From the outcomes, it is confirmed that the enhancement in hardness, wear resistance properties are obtained. This improvement in results is the contribution of heat treatment and formation of Al–Zn–Mg–Cu alloy composites by adding 15% by weight of SiC. Also, it has been revealed that improved properties are the results of the particle size of the Silicon Carbide (SiC) particles.

The enhanced hardness of the composite and base metal will be obtained through the heat treatment method which results in the reduction of wear rate [8]. On account of as–cast material, estimation of the constant of wear is larger than the heat treated material. The cracks will grow at the interface of the matrix and reinforcement, along with the wear process. Heat treated material demonstrate the resistance to wear [9]. Because of the higher ductility and strength of the aluminum matrix, the effectual stress connected on material surface along with the wear progression is less on account of the heat–treated alloys. This occurrence caused a reduction in the cracking propensity of the material surface when contrasted with the as–cast alloy [8]. The heat treatment didn't drastically modify the morphology, but rather the matrix hardening by age hardening occurred, which prompted greater strength & hardness [9].

T6 thermal treatment condition was used to obtain the highest wear resistance. Studies indicate that the better hardening of the material was achieved when the composite was solutionized for 3 hours at 560°C, quenched at 0°C in ice water and aged at 175°C temperature for 07 hrs. Also it is reported that T6 heat–treatment for 07 hrs provides the great hardness to matrix and caused higher wear resistance in MMCs [10]. The yield strength and higher hardness of the material after this heat treatment condition may have the benefit of keeping generation of aluminium debris & reduction in its exchange to the steel surface [11]. After the aging at low temperature (b/n 50°–150°C), the resistance to wear of the materials is observed to be low. Peak aging conditions, at 2000C aging temperature, would increase the abrasion resistance of the composite and as well as the hardness.

In the background aluminium 7075 metal matrix hybrid composite composites have a wide range of scope for the research. Research has to be carried on the aluminium matrix composite reinforced with reinforced with silicon carbide and aluminum oxide in the area of wear in–order to enhance the strength and resistance to mechanical characteristics of the material.

MATERIALS AND PROCESSING

Al–7xxx alloys, for instance, 7075 are commonly used as a part of applications including transport, automobile, marine and also in aerospace, because of their high strength and low weight. The main constituents in the Al7075 are Si=0.4%, Zn = 6.1%, Mg=2.9%. The properties of the Al7075 are density = 2.85g/cc, ultimate strength = 480MPa, elastic modulus = 75GPa, Poissons' ratio = 0.33, melting point = 650^{0}C [12].

Silicon carbide is a ceramic material also known as carborundum, denoted as SiC. It is a blend of silicon and carbon. It is an outstanding abrasive material utilized to prepare grinding wheel and other abrasive parts. Now a day, the SiC material is formed into a technical grade better quality ceramic with excellent mechanical/physical properties. Some of the key properties of silicon carbide utilized here are Density – 3.1 g/cc, melting point – 2730^{0}c, molecular mass – 40.10 g/mol, grit size –16–100grit, Appearance –Black in color [13].

Aluminum oxide, commonly known as alumina (Al_2O_3) is corundum in its crystalline form is widely used in industry. The alumina (Al_2O_3) as a reinforcement [14] is steadier with aluminium and withstand higher temperatures. Some of the key properties of aluminum oxide utilized here are density=3.69g/cc, melting point – 2072^{0}C, mesh size=100–200 mesh, appearance – White in color.

Processing of Al7075–SiC/Al_2O_3 hybrid metal matrix composite is done by using stir casting technique. The procedure followed is displayed in Figure 1.

Density values of hybrid composites increases with increment in weight fractions of the reinforcement. The Density of both SiC and Al_2O_3 are higher than that of aluminum alloy therefore, an increment in the contents of reinforcements will increases the density of the composite. Similar results have been reported in the case of Al_2O_3 reinforced Aluminium composites, SiC reinforced Aluminium composites. Compared to the unreinforced alloy, SiCp and MoS2p contributed to a marginal increase (0.13– 2.7 %) in the density of hybrid composites by 36% and 64% respectively. The density of the Al7075–SiC/Al_2O_3 hybrid metal matrix composite is given in the table 1.

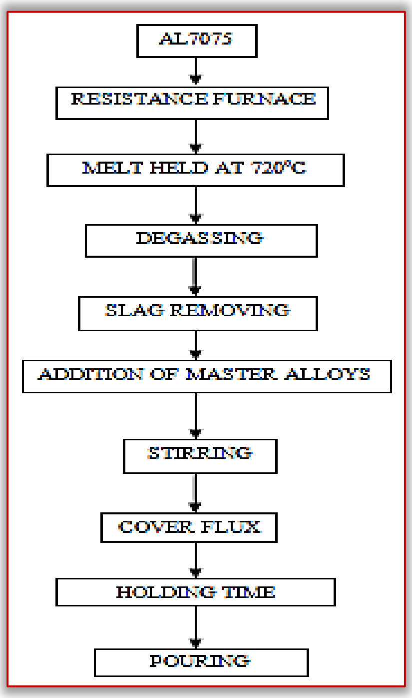

Figure 1: Activity chart of stir casting process

Table 1: Density test calculation

Material Composition	Mass gms	Volume cc	Density g/cc
R1–As cast (Al7075)	5.916	2.142	2.76
R2–Al7075+ 5%Al_2O_3+ 5% SiC	5.7255	2.091	2.73
R3–Al7075+ 10%Al_2O_3+ 10% SiC	6.213	2.256	2.754
R4–Al7075+ 15%Al_2O_3+ 15% SiC	5.9622	2.225	2.679

EXPERIMENTAL PROCEDURE

The Vickers' indentation hardness measurement technique comprises of diamond indenter used to indent the test specimen. The diamond indenters used is having square base with pyramid shape and a point of 136^{o} in–between. Specimen material is subjected to applied load A by the indenter of somewhere in the range of 1gf to 100kgf. The load applied on the specimen through the indenter for 5 to 20 seconds. After removing the applied load, indentation applied on the specimen has been measured for both the diagonals on the surface utilizing a microscope and the average value has been considered. Diagonal area of slant surfaces is determined. The Vickers' hardness is the quotient gained by separating the kgf load by the square mm indentation area.

The term micro–hardness Vickers' indentation test generally uses Vickers diamond pyramid or the Knoop lengthened diamond pyramid to produce static indentations with the load not surpassing 1 kgf. The method for testing is fundamentally the same as that of the standard Vickers' hardness measurement, aside from that it is done on a microscopic scale with the high precision instrument. The surfaces to be indented usually required a metallographic machining. For lesser the load utilized, the higher the surface finish essentially.

SPECIMEN PREPARATIONS

Casting is done by varying the percentage reinforcement of alumina and silicon carbide that is 5, 10 and 15% with respect to the weight of Aluminium7075. The mould 1 size is 12mm in diameter and 100mm in length so as the casting that is taken out from the mould 1. Mould 2 is having 25mm in diameter and 100mm in length. The above said casting is machined to 10mm diameter and 35mm length for casting 1 and 25mm diameter and 1inch length for casting 2. These specimens are polished in a polishing machine for the greater surface finish. Figs 2 to 7 show the casting taken out from the mold and the machined specimens respectively.

Figure 2: Graphite Crucibles

Figure 3: Muffle furnace

Figure 4: Induction Furnace

Figure 5: Mould

Figure 6: Specimen

Figure 7: Specimen

The composite specimen is heat treated at a temperature of 465^{0}C for 02 hrs taken after by quickly quenched in cool water. After quenching the specimens, these are subjected to an age (precipitation hardening) by heat–treatment the specimens to 120^{0}C, maintaining this temperature for 05 hrs and after that taken after cooling in air to room temperature. Then follow the above procedure for hardness testing by using Vickers' hardness instrument.

EXPERIMENTAL RESULTS OF MICROHARDNESS

The below table shows the Vicker's hardness number for specimens of different percentages of reinforcements

Table 2: Vickers' hardness number for specimens

Specimen ID	Composition	Vickers Hardness Number
1	Al7075	106
2	Al7075 + 5%SiC + 5%Al_2O_3	114
3	Al7075 + 10%SiC + 10%Al_2O_3	116
4	Al7075 + 15%SiC + 15%Al_2O_3	109

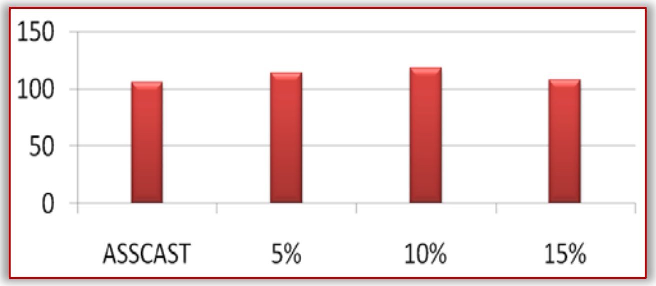

Figure 8: Graph plotted for Vicker's Hardness Number v/s Compositions of Specimens [without heat treatment]

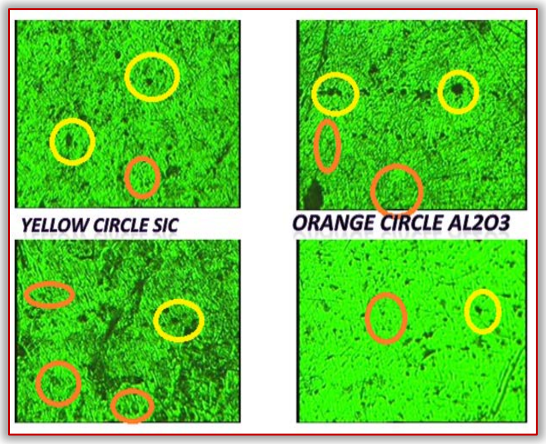

Figure 9: Vickers' Hardness test indentation photos

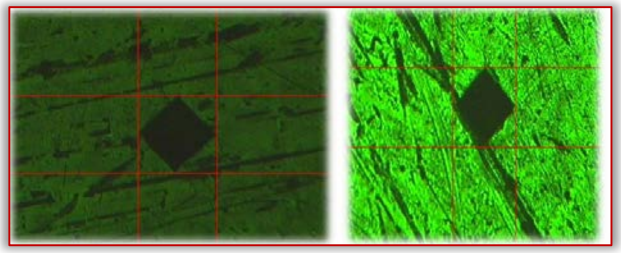

Figure 10: Vickers' Hardness test indentation photos [without heat treatment]

The below table shows the vickers' hardness number for specimens of different percentages of reinforcements on with heat treatment.

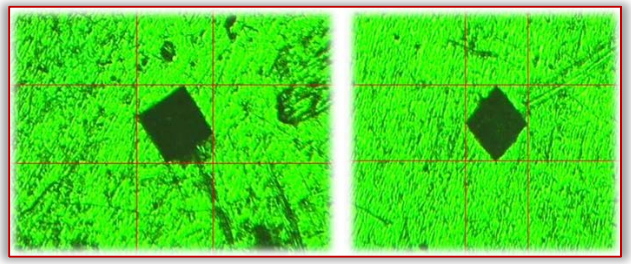

Figure 11: Vickers' Hardness test indentation photos [with heat treatment]

Table 3: Vickers' hardness number for specimens

Specimen ID	Composition	Vickers Hardness Number
1	Al7075	120
2	Al7075 + 5%SiC + 5%Al_2O_3	130
3	Al7075 + 10%SiC + 10%Al_2O_3	140
4	Al7075 + 15%SiC + 15%Al_2O_3	115

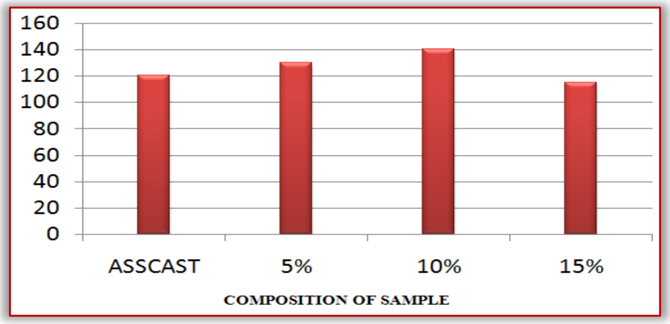

Figure 12: Graph plotted for Vicker's Hardness Number v/s Compositions of Specimens [with heat treatment]

The Fig 13 graph shows the effect of the addition of reinforcements on the composite hardness. The evidence is that as percentage of reinforcement is varied by weight, the hardness number of the composites increased monotonically and significantly from 106 to 116 VHN. It is also observed that the hybrid composite with 10% Sic 10% alumina shown good hardness property. It is reported that the addition of SiC+alumina to Aluminium7075 in metal–alloys lead to superior hardness number and strength.

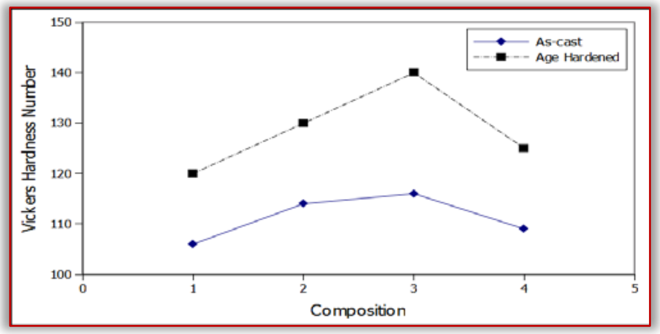

Figure 13: Graph plotted for Vicker's Hardness Number v/s Compositions of Specimens for as–cast and age hardened condition.

Micro–hardness of hybrid composites found incremented with raise in content of filler and enhance in hardness number of Al7075+Al_2O_3+Sic composites are in the range of 110–140VHN for with heat treatment.In T6 heat treated, aged HAMMCs the observed hardness was 120, 130, 140 AND 115 respectively for various wt% of Sic and alumina reinforcement in HAMMCs. It resulted in increase of 20 % of hardness in aged HAMMCs when compared with unaged heat treated HAMMCs. The highest hardness was noticed in composites for aged with 10%SiC+10%Al_2O_3 reinforcement. There is a gain in hardness of 20 % due to heat treatment in HAMMCs. In T6 heat treatment of HAMMCs, the thermal mismatching of matrix and reinforcement thermally promotes dislocation density improvement in dislocation densities outcome in advanced resistance to plastic deformation, led to better hardness.

CONCLUSION

From the experimental results, the following conclusions can be drawn. The incorporation of the SiC &Al_2O_3 constituents in the aluminum metal matrix as the reinforcement content increases the hardness of the material. For 10% reinforcement of SiC and Al_2O_3 to the Al7075 enhances the hardness for both without and with heat treatment. The percentage of enhancement of hardness is 22% with heat treatment compared to without heat treatment for 10% of addition of SiC and Al_2O_3 with Al7075.

Acknowledgement: I wish to thank University B.D.T. College of Engineering (Davangere), VGST–K FIST facility for melting and Material Testing (SJMIT, Chitradurga) for their support in providing facilities for various characterizations of materials and helped me to complete my research work.

References

[1] Jatitz, Whittenberger, J.D. 1990, in Solid State Powder Processing, ed. A.H.Clauer & J.J. deBarbadillo. The Minerals, Metals and Materials Society, Warrendale, PA, p.137.
[2] ASM Handbook, "Composites", ASM International, 21 (2001).
[3] D.M. Miller, Glass Fibers, Composites, Vol 1, 1987, Engineered Materials Handbook,ASM International, , p 45–48
[4] Singla, M, Dwivedi, DD, Singh, L, & Chawla, V. (2009). Development of aluminium based silicon carbide particulate metal matrix composite. Journal of Minerals & Materials Characterization & Engineering, 8(6), 455–467.
[5] Veeresh Kumar GB, Rao CSP, Selvaraj N, Bhagyashekar MS, "Studies on Al6061–SiC and Al7075–Al2O3 Metal Matrix Composites", J. Min. Mat. Char. & Eng. 2010, 9, 43 – 55.
[6] Komai K, Minoshima K, Ryoson H. Tensile and fatigue fracture behavior and water–environment effects in a SiC–whisker/7075–aluminum composite. Compos Sci Technol 1993; 46:59–66.
[7] Rupa Dasgupta and Humaira Meenai, "SiC particulate dispersed composites of an Al– Zn–Mg–Cu alloy: Property comparison with parent alloy", Materials Characterization, Volume 54, Issues 4–5, May 2005, Pages 438–445.
[8] S.Sawla, S Das "combined effect of reinforcement and heat treatment on the two body abrasive wear of aluminium alloy and aluminium particle composites",pp 555–561,2004.
[9] Vencl, A., Bobic, I., Arostegui, S., Bobicd, B., Marinkovic, A. and Babic, M. (2010) "Structural, mechanical and tribological properties of A356 aluminium alloy reinforced with Al2O3, SiC and SiC, graphite particles", Journal of Alloy and Compound, 506: 631–639.
[10] Gomes E.G. and Rossi, Sept 2001, Key Engg. Materials, Vol.189–191, pp. 496–502.
[11] N Singh, Shweta Goyal and Kishore Khanna, July 2010. "Effect of Thermal Ageing on Al Alloy Metal Matrix Composite", Department of Mechanical Engineering, M.E. Thesis, Thapar University, Patiala, India.
[12] Rajesh A M, Mohammed Kaleemulla, Experimental investigations on mechanical behavior of aluminium metal matrix composites, Materials Science and Engineering 149, 2016.
[13] Rajesh A M, Mohammed Kaleemulla, Experimental investigations on mechanical and wear behavior of hybrid aluminium alloy, IJERT, Volume: 05, Issue: 13, pp 128–131, Sep–2016.
[14] Rajesh A M, Mohammed Kaleemulla, Effect of heat treatment on hybrid aluminum metal matrix composites, International Journal of Emerging Research in Management &Technology, Volume–6, Issue–5, pp 548–551, 2017.

ACTA TECHNICA CORVINIENSIS BULLETIN OF ENGINEERING
ISSN: 2067–3809